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Wounding rates in shooting foxes (Vulpes vulpes)

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Abstract

One-hundred-and-ninety-nine shooters in England, Wales and Scotland shot at fox-shaped targets in 35 shotgun regimes including .410 and 12 bore using No 6, BB or AAA shot sizes at 25, 40 or 60 yards, with open and full choke barrels, and skilled, semi-skilled or unskilled shooters. A further 16 regimes used rimfire rifles at 50 yards (both supported using a gun rest and unsupported) and centrefire rifles at 100 and 150 yards, by day and by night. The targets were life-sized paper foxes, traced from a longitudinal section of a real fox and mapped with the internal anatomy. For shotgun trials, the targets were moved across a gap, allowing the shooters 3 or 3.5 s to take aim and fire. For rifle trials, the static targets were raised up for 4 s and then lowered. Fifteen dead foxes, shot with the same ammunition, ranges and angle as in the shooting regimes, were assessed for internal injuries caused by each regime. Ammunition was tested in comparative card-penetration tests. A total of 1085 shotgun shots and 885 rifle shots at the targets were scored as 'killed', 'seriously wounded', 'lightly wounded' or 'missed'. As shooters' skill level increased, the 'kill' rate increased, the 'miss' rate decreased but the 'wounding' rates stayed much the same. No 6 shot 'wounded' because of poor penetration. AAA had poor pattern density at ranges beyond 40 yards. At ranges of up to 40 yards, both AAA and BB shot performed well, BB being the optimum. .410 shotguns with No 6 shot 'wounded' but seldom 'killed'. Rifles 'killed' better than shotguns and 'wounded' less. There was no regime that had no probability of 'wounding'; however, the latter varied dramatically across the trials with different types of gun, ammunition and shooters' skill level. Mitigating factors such as the use of second shots or dogs are discussed.

Keywords: *animal welfare, red fox, rifle, shooting, shotgun, wounding*

Introduction

With the current controversy over hunting the red fox (*Vulpes vulpes*) with dogs, one alternative, shooting, is seen by some as a panacea. Despite repeated calls for scientific evidence on the relative welfare merits of the two methods, none has so far been available. The aim of our study was to quantify, as far as technically feasible, potential wounding rates incurred in shooting foxes, using regimes that are currently legal in UK. In the UK it is legal to shoot foxes with any type of rifle, shotgun or airgun, with any ammunition. Foxes may be shot by stalking with a rifle, by attracting them to a waiting gun using a prey-distress call, by locating them at night with a lamp, opportunistically when shooting other species such as pheasants, or by driving them out of cover using dogs.

Wounding rates in relation to specific shooting regimes for foxes are as yet unknown. Bertsden *et al* (1999) found that 25% of 143 foxes in rural Denmark carried shotgun pellets from previous injuries, but only 4% of 48 urban foxes carried old pellets. Brash (in Mullineaux *et al* 2003) considered that "most adult foxes presented to the surgery have traumatic injuries, usually from gunshot wounds, road traffic injuries or snare injuries" and that "many foxes will tolerate minor gunshot injuries, particularly 'scatter' from shotgun pellets, without any clinical signs". On the other hand, only three out of 2020 foxes at three RSPCA hospitals were hospitalised because they had been shot (A Lindley personal communication 2004). Baker and Harris (1997) assessed the different known causes of mortality of British foxes, such as road deaths, shooting, terriers, snares, lurchers and hounds, and concluded that although an estimated 80 000 foxes were shot and retrieved each year, a further 115 000 fox deaths remained unaccounted for. Thus there is a gap in our knowledge about what happens to foxes that are shot at, but not retrieved.

Many hours, even days, may be expended in getting a shot at a fox. Over four decades, the authors NC Fox and D Wise saw foxes shot both by shotguns and by rifles, by day and by night, and saw some killed and some wounded by all these methods, but during this study period we could not provide enough observers to document sufficient real fox shooting to determine the kill rates ourselves. Although we managed to obtain the Hunt Returns for the Scottish Gun Packs 2002–2003 (Fox *et al* 2003), it is clear that to obtain

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adequate first-hand quantitative data of real fox shooting there are considerable logistical difficulties, particularly in identifying the welfare status of foxes that escape.

When foxes are shot at, some are killed outright (group *k*) and some are completely missed (group *m*). There is no major welfare problem with these two groups. The third group (*w*) covers the foxes that are wounded but not killed outright and either die later or recover, suffering pain and stress in the process. Some of these wounded foxes may be recovered by means of a second shot, or by dogs, and dispatched. Others will escape, and there is no reliable way to differentiate between them and the foxes that have been missed completely. For wounding rates in other species, such as those hunted for food, or in human shooting incidents, some authors have based their estimates on a sub-set of *w* (eg retrieved carcasses at butchers or hospitals), whereas our study was designed to investigate the entire *w* group.

Shooting foxes is not a single, standard activity; rather, it is a multi-faceted activity with a host of variables such as type of weapon (rifle or shotgun), calibre, choke, size and number of shot and load, range, ability of the shooter, movement and direction of the fox, exposure time, terrain and weather. Attitude of the shooter is also important; willingness to shoot at extreme range, or conversely to forgo a chance shot, strongly influences the risk of wounding. When looking at welfare it is not just the welfare of the target that needs to be considered. A fox shot in late spring may be a vixen with dependent cubs that might starve (Macdonald *et al* 2000). A non-target species such as a dog or small deer, or even a human, may be shot by mistake. Identifying which shooting regimes cause least wounding could lead to regulations, codes of practice or training that might confer some practical welfare benefit. This would also provide a 'welfare benchmark' for other methods of killing foxes, such as dogs or snares.

Methods

To use live foxes for shooting trials would be unethical, so we used artificial targets to simulate as closely as possible the conditions found in real life situations. With artificial targets one can see which ones have been hit ($k + w$) and which have been missed (*m*).

The wounding rate is based on the outcome of a single shot. The shot is our statistical starting point, with three possible outcomes; it kills, wounds or misses. An individual fox can be missed or wounded by multiple shots before finally being killed by a last shot or escaping, therefore wounding rate (WR) can be calculated thus:

$$\text{WR} = \frac{(S - k - m) \times 100}{S}$$

where S = number of shots.

Thus while a live fox can be scored as more than one outcome, a shot at a model target can be scored as only one outcome. This is important because many of the published wounding rates are not adequately defined, or present data that cannot be used for comparisons. An initially wounded animal may be killed later, and classed as killed. If a study does not include an examination of all the escaping animals there is no way to determine which have been completely missed and which have been wounded. It is impossible to do this in real-life shooting studies or in studies of hospitalised animals.

The target

The target fox was modelled on an adult vixen weighing 5.0 kg and selected from a group of 14 foxes as being intermediate between the large males and the smaller sub-adults. It was frozen in a trotting position and the silhouette traced out exactly onto clear acetate. The specimen and the silhouette were used to produce a life-sized full-colour image of the fox's side-view. The specimen was then sawn longitudinally, the longitudinal section was overlaid with clear acetate and the major organs and skin outline were traced in. Exact outlines were thus obtained for the abdominal and thoracic cavities, the brain and spinal cord, and the heart, trachea and buccal cavity. Dissections of the limbs, spine, and pelvic and thoracic regions were used to trace in the exact outlines of the bones when viewed from the side. All of the acetate overlays were then combined to produce a target that from a few metres looked like a normal fox, but at close quarters was clearly mapped with anatomical details. A data sheet for the shooting regime was printed on the target between the legs. We thus had an anatomically accurate standard fox target and this was scanned and printed in both right- and left-facing positions.

The broad-side position is the most vulnerable one. The brain, heart, liver and major vessels are fully exposed with the minimum of protective bone and muscle mass to absorb shot penetration. Also exposed is a considerable area of the body that is made up of tissue, such as gut, haunches and legs, that if hit would lead to wounding rather than immediate death. The frontal view, on the other hand, presents a relatively compact target that may be a little harder to hit, but is also perhaps less likely to be wounded. The tail-on view presents little that is vulnerable. Most of the vital organs are well protected by the lumbar mass and gut which absorbs the penetration of all but the most powerful of shot and leads to a high risk of wounding (Bucknell 2001).

The printed paper target was held onto a renewable plywood backing by rubber bands and the target was mounted on a wooden sledge so that only the fox was visible to the shooter. The sledge had curved runners so that there was a tendency for the target to rock as it was towed. At each end of the sledge was a 50 m rope, adjusted so that it pulled the sledge along a straight track. The target track line was 3 m behind a screen, to prevent the sledge colliding with the screen. A person at each side was designated to run, pulling the sledge past a gap in the screen. The gap was 8 yards (7.3 m) for the 25 yard (22.7 m) range, and 10 yards (9.1 m) for the 40 and 60 yard ranges (36.4 and 54.5 m respectively). Narrower arcs of fire than these did not give the shooter sufficient time to raise the gun and aim adequately. The fox took approximately 3 s to cross the gap at 25 yards and 3.5 s at the two longer ranges. For the rifle trials the sledge was not used. Instead, the target was raised up on

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hinges and was exposed, static, for 4 s before being lowered again. Measurements were in imperial units to suit the needs of the shooters. All procedures were recorded on film (Faraway Films 2003).

Of course a printed target does not enable as accurate an analysis as would a captive live fox; for example, it cannot show how pellets may be deflected by bone. We have to view our results within the constraints of these inevitable limitations.

The regimes

The regimes were selected to investigate some scenarios that meet government guidelines for fox shooting (Geddes 2001). These guidelines are not mandatory and appear to be little known. We therefore investigated further scenarios that are legal and which we believe are used in real life from time to time. We did not investigate extreme scenarios such as the use of airguns, as reported by Harris (2003) from X-rays of hospitalised foxes.

Shooter classification

A total of 199 shooters participated in the trials and shoots were held in England, Scotland and Wales according to a standardised protocol. Where possible, fox shooters used their own guns. Unskilled shooters used borrowed guns. We assigned shooters into one of three categories:

a. *Skilled* — people who shoot significant numbers of mammals or birds each year.

b. *Semi-skilled* — people who possess a gun and shoot a few times per year but do not consider themselves to be above-average shots.

c. *Unskilled* — people who have seldom or never fired a gun before and need teaching how to manage it. Anyone who was legally eligible to fire a gun was eligible to participate in the trials.

We encountered shooters who attended fox shoots but who were, to all intents and purposes, unskilled. Several did not know the choke ratings for their guns. Others were skilled with rifles but unskilled with shotguns or vice versa.

These skill categories were somewhat arbitrary; shooter ability is, after all, a gradient and does not fall into discrete groupings. In the .410 regime the skill levels were pooled but the sample was still in the same ratio as for the 12 bore regimes, ie approximately 25% unskilled, 50% semi-skilled and 25% skilled.

Shotgun shooters stood facing the target area with the gun in the 'gun down' position. They could anticipate the imminent appearance of the target but could not dictate it or predict it; when they saw the fox target appear they raised the gun and fired. They were limited to a single right crossing and a single left crossing in each regime and were not allowed more than four consecutive shots so that they had limited opportunity to improve on their initial performance through repetition. Rifle shooters used gun rests, usually small 'bean bags' laid on the bonnet of a vehicle, or they used bipods attached to the rifle, shooting from the prone position. All rifles had telescopic sights. In the unsupported regimes the shooters stood and aimed the rifle with no mechanical support.

Choke ratings

A choke is a slight constriction at the muzzle of the barrel that 'focuses' the pellets into a tighter pattern. The shotguns were the same ones that the shooters normally used for shooting foxes and had a variety of chokes. Two regime categories were used: the first included true cylinder (0 choke) and improved cylinder (equivalent to ¼ choke), normally the 'open' barrel. The second is the 'choke' barrel, including ¾ and full choke. With the .410 it was difficult to find guns with less than ½ choke; therefore, the open regime included 0–½ choke.

Ranges

The ranges were 25 yards (22.7 m), 40 yards (36.4 m) and 60 yards (54.5 m) for shotguns and 50, 100 and 150 yards (55, 110 and 165 m) for rifles. The 25 yard (22.7 m) range is midway between the government guideline of 25 m for shotguns on foxes and the British Association for Shooting and Conservation's guideline of 20 m; 40 yards is a normal accepted limit for a shotgun when game-shooting, and 60 yards would be considered a 'long' shot, sometimes used for geese. For rifles, 50 yards is about the useful limit for a .22 rimfire, and 100–150 yards are typical ranges for a centrefire rifle.

Rifles

At 50 yards some regimes were shot with no support for the rifle and others with a support, resting on a vehicle, beanbag or bipod. For lamping (shooting by spotlight at night), all procedures were the same except that the shooter had an assistant to manage the lamp.

Ammunition

Ammunition and guns of supposedly the same specification can vary according to manufacturer, brand name and even batch. The cartridges we used differed slightly from those of the same specification detailed by Bucknell (2001). We therefore tried as far as possible to use the same guns as are actually used for shooting foxes and we used standardised ammunition for the regimes as follows:

.410 Eley Fourlong No 6 containing 111 pellets weighing 12 grams.

12 bore Eley Grand Prix No 6 containing 307 pellets weighing 30 grams.

12 bore Lyalvale Express BB containing 103 pellets weighing 36 grams.

12 bore Lyalvale Express AAA containing 43 pellets weighing 36 grams.

The 12 bore cartridges were chosen as representing those used at a driven pheasant shoot (No 6) and those used on fox shoots (BB and AAA). Rifle ammunition was provided by each shooter, zeroed specifically for each rifle and range by their owners. (Zeroing is the adjustment of the sights so that bullet placement coincides with sight positioning.) Unskilled shooters were provided with zeroed rifles and

Table 1 Ammunition penetration characteristics in sheets of Daler-Rowney 302001042 Poster board.

Shotguns	Range (yards)	Shot size	Minimum	Maximum	Mean	n
Four ten	40	6	3	11	7	13
12 bore	40	6	5	11	8	18
Four ten	25	6	7	11	9	28
12 bore	25	6	8	12	10	27
12 bore	40	BB	17	20	18.5	15
12 bore	60	AAA	17	22	19.5	9
12 bore	25	BB	16	27	21.5	53
12 bore	40	AAA	25	34	29.5	5
12 bore	25	AAA	30	32	31	5
0.22 subsonic	100		35	41+	41+	5
0.22 subsonic	50		41+	41+	41+	5

basic instructions in their use. They were not allowed to practice or zero the rifles themselves. Rifle calibres included .22 rimfire (at 50 yards) and .222, .22-250, .223, .243, 6mm PPC, .25–06 and .308 in centrefire (at 100 and 150 yards). In the .22 regime, the 'wounding' was scored as for .22 LR high velocity hollow point ammunition. The .22 rimfire rifles have a smaller range and muzzle velocity than the centrefire rifles.

The penetration of the test ammunition is shown in Table 1, measured in number of sheets of card actually penetrated. Penetration depends on a host of factors, such as shot size, hardness, deformation, clumping, powder charge and range. Pellets of all sizes, being round and hardened, penetrate making a hole about the same diameter the whole way unless they hit bone. Hollow nose .22 bullets expand or have tumbled by about a third of their penetration, making a hole 3–4 times their entry diameter. Penetration tests were not conducted on the centrefire rifles because it is already known that their performance is more than adequate to kill foxes (Bucknell 2001).

Just because a regime was included does not mean that it is suitable for foxes, but the regimes are all legal in Britain. In discussions with shooters during the trials, some claimed to have shot foxes with .410s and several claimed to have shot at foxes at 80–120 yards with intent to slow them down sufficiently for dogs to catch them or for them to die later. Therefore we explored the performance of all these regimes to see if some are suitable for foxes from the welfare point of view.

Analysis of fox carcasses

The shooters provided 15 dead fox carcasses for assessment of the penetration and damage caused by projectiles shot in the same regimes as in the target trials. Because choke rating and skill level of the shooter have no effect on penetration, this sample size was sufficient to cover all permutations. Foxes were either shot directly according to one of the regimes during the course of normal pest control, or were re-shot after death. The dead foxes, either fresh-killed or thawed, having originally been killed either by a humane killer or by snaring, were suspended in a broad-side position similar to the fox target and shot with the appropriate regime of ammunition and range. They were delivered to the International Zoo Veterinary Group (IZVG) frozen and were subsequently thawed for examination. All carcasses were radiographed and then necropsied to assess penetration of, and lesions caused by, shot. Dorsoventral and lateral radiographs were taken using standard dog positioning and exposure to determine the location of shotgun pellets or rifle bullet fragments within each carcass. A complete necropsy, including skinning of the entire carcass and examination of all organ systems, was performed on each animal. However, full post mortem assessment and interpretation of lesions was not possible in all cases because of autolysis and freeze/thaw artefact.

Scoring

Two veterinary experts (IZVG and D Wise) scored the targets together, reaching a consensus opinion on each target. Scoring was based on the positioning of strikes on the targets, with the outcomes 'kill', 'serious wound', 'light wound' and 'miss' indicating the assumed outcome for a live fox under these circumstances.

'Kill'

A. Disruption of the central nervous system with rapid/immediate unconsciousness and immediate knock-down. This was judged to be obtained by an effective hit to the brain or disruption of the spinal cord above thoracic region 1 (T1).

B. Rapid hypovolaemia with almost immediate unconsciousness and knock-down. This was judged to be obtained by a substantial hit to the heart or great vessels within the thorax.

'Serious wound'

C. Slower development of fatal hypovolaemia or pneumothorax. This was judged to be obtained by a substantial hit to the thorax but which misses the heart or great vessels, or a substantial hit to the liver.

D. Non-fatal immobilisation. As this does not achieve a kill with a single shot, we resisted counting this as a kill but subsequent retrieval is probable. Immobilisation was judged

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Table 2 The test regimes listed in order of increasing probabilities of wounding. Regimes in bold meet government guidelines (Geddes 2001).

Regime types										Probabilities (%)				Wounding 'tax'		
Regime	Calibre	Choke	Ammunition	Distance (yards)	Skill level	Daytime	Armrest	Shooters	Shots	Kill	Serious wound	Light wound	Miss	Seriously wounded per fox killed	Lightly wounded per fox killed	Total wounded per fox killed
R12	>.22	(Rifle)	Bullet	100	Skilled	Night	Yes	10	50	90.0	8.0	2.0	0.0	0.1	0.0	0.1
R14	>.22	(Rifle)	Bullet	150	Skilled	Day	Yes	10	50	88.0	12.0	0.0	0.0	0.1	0.0	0.1
R10	>.22	(Rifle)	Bullet	100	Skilled	Day	Yes	11	55	81.8	12.7	3.6	1.8	0.2	0.0	0.2
R9	>.22	(Rifle)	Bullet	100	Unskilled	Day	Yes	12	60	75.0	15.0	0.0	10.0	0.2	0.0	0.2
R4	0.22	(Rifle)	Bullet	50	Skilled	Night	Yes	11	55	81.8	16.4	0.0	1.8	0.2	0.0	0.2
S25	12 bore	3/4-Full	6	25	Unskilled	Day	No	12	24	54.1	16.6	0.0	29.17	0.3	0.0	0.3
S44	12 bore	3/4-Full	BB	40	Semi	Day	No	20	39	69.2	20.5	0	10.3	0.5	0.0	0.5
S16	12 bore	0-1/4	AAA	25	Unskilled	Day	No	12	22	45.5	22.7	4.5	27.3	0.5	0.2	0.7
R8	0.22	(Rifle)	Bullet	50	Skilled	Night	No	12	60	53.3	23.3	3.3	20.0	0.4	0.1	0.5
S29	12 bore	3/4-Full	AAA	25	Semi	Day	No	18	38	44.7	23.7	2.6	28.9	0.6	0.0	0.6
S41	12 bore	0-1/4	BB	40	Semi	Day	No	19	37	64.9	27.0	2.7	5.4	0.6	0.0	0.6
R11	>.22	(Rifle)	Bullet	100	Unskilled	Night	Yes	12	60	50.0	28.3	3.3	18.3	0.6	0.1	0.6
R15	>.22	(Rifle)	Bullet	150	Unskilled	Night	Yes	11	55	45.5	27.3	9.1	18.2	0.6	0.2	0.8
S27	12 bore	3/4-Full	6	25	Skilled	Day	No	12	24	66.7	29.2	4.1	0.0	0.5	0.1	0.6
S26	12 bore	3/4-Full	6	25	Semi	Day	No	21	40	65.0	30.0	2.5	2.5	0.5	0.0	0.6
S13	12 bore	0-1/4	6	25	Unskilled	Day	No	13	25	28.0	32.0	4.0	36.0	1.1	0.1	1.3
S30	12 bore	3/4-Full	AAA	25	Skilled	Day	No	13	25	56.0	32.0	4.0	8.0	0.5	0.1	0.6
R13	>.22	(Rifle)	Bullet	150	Unskilled	Day	Yes	13	65	36.9	32.3	7.7	23.1	0.9	0.2	1.1
R6	0.22	(Rifle)	Bullet	50	Skilled	Day	No	11	55	40.0	34.6	3.6	21.8	0.9	0.1	1.0
R16	>.22	(Rifle)	Bullet	150	Skilled	Night	Yes	10	50	70.0	22.0	8.0	0.0	0.3	0.1	0.4
S34	12 bore	3/4-Full	AAA	40	Unskilled	Day	No	12	24	25.0	33.3	8.3	33.3	1.5	0.3	1.8
S28	12 bore	3/4-Full	AAA	25	Unskilled	Day	No	11	22	36.4	36.4	0.0	27.3	1.1	0.0	1.1
S45	12 bore	3/4-Full	BB	40	Skilled	Day	No	10	22	54.6	40.9	0	4.6	0.6	0.1	0.7
S42	12 bore	0-1/4	BB	40	Skilled	Day	No	9	17	47.1	41.2	5.9	5.9	1.0	0.2	1.2
S37	12 bore	3/4-Full	AAA	60	Unskilled	Day	No	12	25	4.0	44.0	0.0	52.0	11.0	0.0	11.0
R1	0.22	(Rifle)	Bullet	50	Unskilled	Day	Yes	9	45	53.3	42.2	4.4	0.0	0.8	0.1	0.9
S43	12 bore	3/4-Full	BB	40	Unskilled	Day	No	10	19	47.4	42.1	5.3	5.3	0.8	0.1	0.9
S19	12 bore	0-1/4	6	40	Unskilled	Day	No	11	22	27.27	40.9	9.09	22.7	1.3	0.4	1.7
S18	12 bore	0-1/4	AAA	25	Skilled	Day	No	13	25	40.0	40.0	12.0	8.0	1.0	0.3	1.3
S24	12 bore	0-1/4	AAA	40	Skilled	Day	No	14	26	42.3	42.3	7.7	7.7	1.0	0.2	1.2
S14	12 bore	0-1/4	6	25	Semi	Day	No	25	49	48.9	44.9	2.0	4.1	0.9	0.0	1.0
S17	12 bore	0-1/4	AAA	25	Semi	Day	No	21	40	35.0	45.0	2.5	17.5	1.2	0.1	1.3
R7	0.22	(Rifle)	Bullet	50	Unskilled	Night	No	11	55	12.7	40.0	14.6	32.7	3.1	1.1	4.3
R2	0.22	(Rifle)	Bullet	50	Skilled	Day	Yes	10	50	52.0	46.0	2.0	0.0	0.9	0.0	0.9
S33	12 bore	3/4-Full	6	40	Skilled	Day	No	16	32	46.9	43.7	9.4	0.0	1.1	0.2	1.3
R3	0.22	(Rifle)	Bullet	50	Unskilled	Night	Yes	13	65	50.8	49.2	0.0	0.0	1.0	0.0	1.0
S36	12 bore	3/4-Full	AAA	40	Skilled	Day	No	16	32	28.1	50.0	0.0	21.9	1.8	0.0	1.8
S40	12 bore	0-1/4	BB	40	Unskilled	Day	No	8	14	28.6	50.0	0	21.4	2.1	0.1	2.3
S15	12 bore	0-1/4	6	25	Skilled	Day	No	13	26	50.0	50.0	0.0	0.0	1.0	0.0	1.0
S32	12 bore	3/4-Full	6	40	Semi	Day	No	18	34	38.2	44.1	14.7	2.9	1.6	0.4	2.0
R5	0.22	(Rifle)	Bullet	50	Unskilled	Day	No	11	55	23.6	43.6	16.4	16.4	1.8	0.7	2.5
S20	12 bore	0-1/4	6	40	Semi	Day	No	19	37	35.1	48.7	8.1	8.1	1.6	0.3	1.9
S35	12 bore	3/4-Full	AAA	40	Semi	Day	No	25	46	19.6	52.1	2.2	26.1	2.4	0.1	2.5
S31	12 bore	3/4-Full	6	40	Unskilled	Day	No	11	22	27.3	54.5	0.0	18.2	1.9	0.0	1.9
S02	0.410	0-1/2	6	25	Semi	Day	No	31	58	10.3	43.1	22.4	24.1	4.2	2.2	6.3
S38	12 bore	3/4-Full	AAA	60	Semi	Day	No	22	43	6.9	51.2	9.3	32.5	5.0	1.2	6.2
S23	12 bore	0-1/4	AAA	40	Semi	Day	No	20	40	10.0	62.5	2.5	25.0	6.5	0.3	6.7
S22	12 bore	0-1/4	AAA	40	Unskilled	Day	No	13	25	12.0	68.0	0.0	20.0	5.7	0.0	5.7
S21	12 bore	0-1/4	6	40	Skilled	Day	No	14	27	25.9	70.4	3.7	0.0	2.7	0.1	2.9
S39	12 bore	3/4-Full	AAA	60	Skilled	Day	No	11	22	13.6	77.3	0.0	9.1	6.7	0.0	6.7
S08	0.410	3/4-Full	6	25	Semi	Day	No	31	62	6.5	58.1	25.8	9.7	9.0	4.0	13.0

to be achieved by a substantial hit to the spine between T1 and lumbar region 4 (L4), or by severe damage to two or more limbs.

E. Serious wounding. This includes all other serious wounding but, unlike C and D, is not necessarily ultimately fatal. The judgement here was based on a considerable degree of soft-tissue damage, or serious damage to the face or a single limb. Abdominal penetration, which did not result in C, was always E, because of the risk of peritonitis.

'Light wound'

F. This was judged to include light wounding, varying from a considerable light scatter from a .410 to the slightest cut of the outer line of the silhouette. This was normally expected to be a recoverable injury.

'Miss '

G. Includes projectiles that travel through the fur, but do not touch the skin line.

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Table 3 Summary of the ANOVA: influence of skill level on outcome of the shooting and percent probabilities of outcome with shooter skill level.

	Kill %	Serious wound %	Light wound %	Miss %
Shotguns				
ANOVA	$F_{2,1082} = 5.46$, $P = 0.00069$	NS	$F_{2,1082} = 5.86$, $P = 0.0197$	$F_{2,1082} = 23.23$, $P < 0.0001$
Unskilled	29.92	39.75	2.87	27.46
Semi-skilled	32.68	43.34	8.53	15.45
Skilled	42.45	47.12	4.32	6.12
Rifles				
ANOVA	$F_{1,883} = 62.14$, $P < 0.0001$	$F_{1,883} = 17.66$, $P < 0.0001$	$F_{1,883} = 7.37$, $P = 0.007$	$F_{1,883} = 18.53$, $P < 0.0001$
Unskilled	43.70	34.57	6.74	15.00
Skilled	69.18	21.88	2.82	6.12

NS = no significant difference

Table 4 Performance differences for shotguns and rifles across all regimes.

	Kill %	Serious wound %	Light wound %	Miss %
ANOVA	$F_{1.1968} = 94.51$, $P < 0.0001$	$F_{1.1968} = 48.47$, $P < 0.0001$	NS	$F_{1.1968} = 10.59$, $P = 0.006$
Shotgun	34.56	43.50	6.18	15.76
Rifle	55.93	28.47	4.86	10.73

NS = no significant difference

Table 5 Performance differences for shotgun pellet size.

	Kill %	Serious wound %	Light wound %	Miss %
ANOVA	$F_{2,1082} = 23.07$, $P < 0.0001$	NS	$F_{2,1082} = 10.82$, $P < 0.0001$	$F_{2,10822} = 18.63$, $P < 0.0001$
6	35.04	44.40	9.75	10.79
BB	56.76	33.11	2.03	8.11
AAA	26.81	45.93	3.74	23.52

NS = no significant difference

We made a judgement, based on the penetration tests and on the pathology studies, of how much impact or penetration would have occurred in a 'substantial hit'. For example, a single high-velocity round in the chest would produce a B or possibly a C, but a No 6 pellet at 40 yards would be unlikely to achieve either, unless a considerable group of pellets squeezed between the ribs. Targets, with rifle, AAA or BB on the brain area were scored A, but at 40 yards even two No 6 pellets on the brain area were, at most, an E.

Data processing and statistical analysis

The analysis of the data was performed with SAS (1986) using ANOVA and frequency procedures. All data were tested for normality within the SAS dataset. The SAS analysis programmes and the dataset are available from the website of the International Wildlife Consultants (http://www.falcons.co.uk/default.asp?id=15). Excel software was used to prepare graphs from SAS result tables. Probabilities for each different shooting regime were sorted by percentage into the 'kill', 'serious wound', 'light wound' and 'miss' categories to standardise the data. The level of significance was set as $P < 0.05$. In the dataset we randomly selected one shot per shooter per regime in each direction.

Results

The summary of shooting regimes and the sample sizes of the tests are given in Table 2.

Influence of shooter skill

The percent probabilities of outcome of the shooter skill levels are given in Table 3. Unskilled shooters 'kill' less and 'miss' more than skilled shooters. Skill has a significant influence on the 'kill' rate for both rifles and shotguns. Only 'serious wounding' by shotguns was not affected by skill.

Type of gun

Shotguns 'killed' less, 'seriously wounded' more and 'missed' more than rifles, but had similar levels of 'light wounding' (Table 4).

Shot size

For shotgun pellets, BB had the highest probability of 'killing' and the lowest probability of 'wounding' or 'missing' (Table 5). There are significantly more 'kills' using BB shot, whereas AAA and No 6 shot incur the greatest number of 'serious wounds'. No 6 has insufficient penetration whereas AAA has too low a pattern density.

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Table 6 Outcome probabilities for shooting at different ranges.

	Kill %	Serious wound %	Light wound %	Miss %
Rifles				
ANOVA	$F_{2,882}$ = 24.19, P < 0.0001	$F_{2,882}$ = 17.14, P < 0.0001	NS	NS
50 yards	45.91	36.82	5.45	11.82
100 yards	73.33	16.44	2.22	8.00
150 yards	58.18	24.09	6.36	11.36
Shotguns				
ANOVA	$F_{2,1082}$ = 16.17, P < 0.0001	$F_{2,1082}$ = 5.77, P = 0.0032	NS	$F_{2,1082}$ = 10.49, P < 0.0001
25 yards	37.92	38.54	8.33	12.51
40 yards	36.12	46.02	4.47	13.40
60 yards	7.78	55.56	4.44	32.22

NS = no significant difference

Table 7 Outcome probabilities for choke (12 bore shotguns only).

	Kill %	Serious wound %	Light wound %	Miss %
ANOVA	NS	NS	NS	NS
0–¼	36.57	46.06	4.17	13.19
¾–Full	38.84	39.77	3.75	17.64

NS = no significant difference

Table 8 Outcome probabilities when shooting rifles by day and by night.

	Kill %	Serious wound %	Light wound %	Miss %
ANOVA	NS	NS	NS	NS
Night	56.00	27.56	4.89	11.56
Day	55.86	29.43	4.83	9.89

NS = no significant difference

Table 9 The influence of a gun support at 50 yards (45.5 m).

	Kill %	Serious wound %	Light wound %	Miss %
ANOVA	$F_{1,1883}$ = 69.99, P< 0.0001	$F_{1,883}$ = 6.56, P = 0.0106	$F_{1,883}$ = 12.23, P = 0.0003	$F_{1,883}$ = 47.11, P < 0.0001
Supported	63.79	26.21	3.33	6.67
Unsupported	32.89	35.11	9.33	22.67

Influence of distance

For rifles, the probabilities of 'light wound' and 'miss' do not depend on distance, whereas in shotguns all except 'light wound' depend on distance (Table 6).

Influence of choke (12 bore shotguns only)

Choke had no significant effect on outcome (Table 7).

Influence of night and day (rifles only)

Rifle shooters shot as well during the night as they did during the day (Table 8).

Influence of a gun support

All rifle trials, apart from one of the 50 yard regimes, were carried out using a rest; absence of a rest significantly reduced performance (Table 9).

Influence of shotgun calibre

The 12 bore 'killed' much more effectively than the smaller .410. Although 'miss' rates were similar, the .410 inflicted significantly more 'light wounds' than the 12 bore (Table 10).

Wounding rate per shot fired

Most of the wounds were 'serious wounds' and would in most cases have led to death within a day or two. Even the best regimes incurred a 'wounding' rate per shot fired of 10%, and 'light wounding' was scattered across most of the regimes (Figure 1).

Wounding rate per fox killed

In order to shoot one fox dead there is a probability that additional foxes will be shot at and wounded — a welfare

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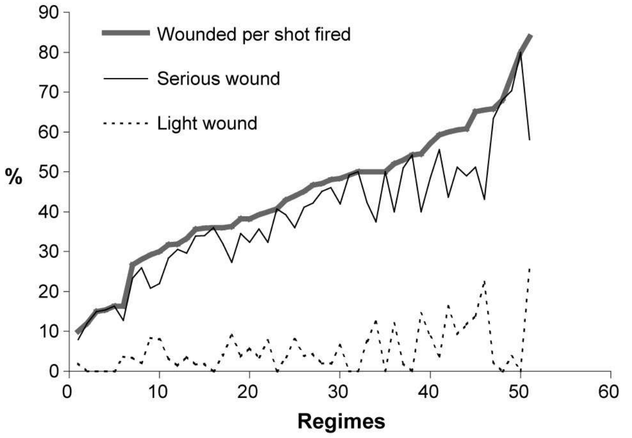
Table 10 Comparative outcome probabilities for shotgun calibres.

	Kill %	Serious wound %	Light wound %	Miss %
ANOVA	$F_{1,1083} = 42.58$, $P < 0.0001$	NS	$F_{1,1083} = 80.86$, $P < 0.001$	NS
12 bore	37.82	42.59	3.94	15.65
Four ten	8.33	50.83	24.17	16.67

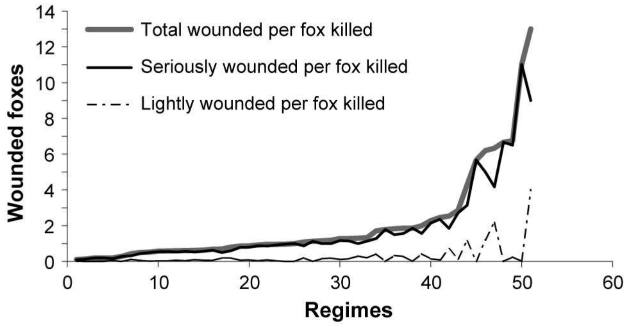
NS = no significant difference

Figure 1



Wounding rate per shot fired. The tested regimes are ranked according to the percentage probabilities of both serious and light wounding, based on data in Table 2.

Figure 2



Wounding rate per fox killed. Regimes are ranked according to wounds incurred per fox killed (see Table 2).

'tax'. The best regimes scored 0.1 foxes 'wounded', or 10% for each fox 'killed'. The first 25 regimes scored one or less foxes 'wounded' per fox 'killed' (ie ≤100%). The remaining 26 regimes showed 1–13 foxes 'wounded' for each fox 'killed' (Figure 2).

Discussion

Definitions and scoring

There is no real precedent for scoring 'wounds' on anatomical fox targets. On their first attempt to score the targets, the veterinary experts worked entirely independently according to their own definitions (Fox *et al* 2003). Although the trends in the results were consistent, there were variations that were traceable to differences in definitions. We therefore defined more clearly terms such as 'killed' and 'seriously wounded'. For example, 'killed' requires consideration of what is meant by 'dead', how long it takes for this state to be reached and what damage needs to be incurred in order for it to be reached. 'Wounds' on the other hand may also be mortal, but because death is not achieved within a certain time frame there is a period in which the animal is still conscious and possibly suffering before it dies. The 'seriousness' of the wound is by no means proportional to the presumed suffering. A seriously wounded animal may die in a few minutes or hours, whereas a lightly wounded animal may take days or weeks to either die or recover.

We could not predict whether the fox would have recovered from its wounds or how many hours it would have taken to die or to recover. Nor could we say what levels of pain or suffering it might have experienced in the process. A head shot might cause the quickest death but also risks causing horrific wounds (such as a smashed lower jaw); chest shots may delay brain-death slightly but are less risky.

Training 'skilled marksmen'

Skilled shooters tended to 'kill' more and 'miss' less but, with shotguns, their 'wounding' rate scores were not markedly different from unskilled shooters. Also, some people who had never fired a gun before but who appeared to have good hand-to-eye coordination produced better scores than some experienced shooters. Therefore, experience did not always equate to increased skill. The benefits of shooter training lie not only in improving marksmanship, but also in teaching when *not* to fire. The limiting of shots to the best opportunities is the best way to increase the kill ratio and reduce the wounding, and this requires a proper awareness of the limitations of both gun and ammunition being used. Of course, the shotgun shooters were faced with a moving target, while the rifle shooters faced a static one; should those conditions be reversed, the outcomes would be very different.

Comparisons of wounding rates

Reports on wounding rates have been based on different aspects that are not directly comparable. Studies such as Ericsson and von Essen (1998) on elk shooting, and Bradshaw and Bateson (2000), Urquhart and McKendrick (2003), Bertsden (1999), Brash (in Mullineaux *et al* 2003) and Swann (2000) who examined animals for shot wounds, are not able to account for all of the animals or shots fired

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in the original sample and are therefore inconclusive for comparative purposes.

The wounding rate per shot fired is a statistically sound starting point. It allows comparisons with other shooting regimes and with the shooting of other species. In the field, this initial wounding rate may be rapidly reduced by further shots or the use of dogs; it is therefore a maximum value.

The second shot

In real life, many wounded foxes are promptly killed by a second or third shot. About 32.7% of 574 shots fired by Scottish Gun Packs shooters were repeat shots (Fox *et al* 2003). The strategy of second shots depends on the priorities of the shooter. Bertsden (1999) examined the use of the second shot in shooting flying mallard. When the second shot was reserved as a 'cripple stopper', overall wounding was reduced, but when used on apparently uninjured ducks, then wounding increased.

In pest control the first priority is to put the fox out of action. Our shooters claimed to have shot at foxes with shotguns at up to 120 yards. Several shots (up to 11) were fired at one fox. For pest control, when the carcass is not required, it is logical to fire at extreme ranges on the off chance that a lucky pellet might hit a vital spot. According to this logic, a long shot has at least a slim chance, whereas a withheld shot has no chance at all.

Our rifle shooters who shot foxes as a sport took pride in their accuracy and kill rate. When time was not a consideration, they could afford to pick their single shots. However, in pest control situations, cost effectiveness may take priority over welfare. Reynolds (2000) found that 0.2–0.6 foxes per hour could be killed by lamping in autumn and winter but that this figure dwindles as fox density decreases. If one searches for several hours at night and gets just a glimpse of one fox, there is a temptation to take a chance and shoot. Thus, by spring, many foxes are 'lamp-shy', having survived previous attempts to shoot them. Additionally, in pest control, a priority is to kill the most animals for the least effort, and cubbing time in February–May is the main season for shooting foxes at night with a lamp.

Dogs

With shotguns it is common to use dogs to flush the foxes into shooting range. If the shooter shoots at but fails to kill the fox, it may return to cover or move beyond shooting range. The dogs can be used to pick up the scent line quickly and have a chance to catch the fox, especially if it is wounded. In the Scottish Gun Pack returns, 54.9% of the escaping foxes were killed by the hounds (Fox *et al* 2003).

Animal welfare implications

The wounding rate per fox killed treats wounding as a 'tax' on killing, in this case through shooting. But it does not depend on shots being fired, and therefore can be used for comparisons with other methods, such as trapping, snaring or dogs. All of these methods are used to kill other species and their welfare performance may vary from species to species (Sainsbury *et al* 1995). Our wounding rates would probably be halved in real life by further shooting or by the use of dogs, but the question arises: what rates are acceptable? For some of the methods, such as traps, poisons and gasses (Fox & Macdonald 1997), there are already some agreed standards or welfare benchmarks. Agreed specific welfare criteria (such as the catch-to-kill interval) are used to assess the method against internationally recognised (ISO) standards (Anon 1998). The Agreement on International Humane Trapping Standards has been agreed by the EC, but not enacted by the Member States, and only applies to fur-bearing species. The testing procedures proposed within Annex 1 of this Agreement have been carried out on new traps since 1992 (Elliot Morley MP in reply to Peter Luff MP, Parliamentary Question 99, 30 April 2003) but we have not been able to trace these results. In the case of restraining traps, these tests require a sample size of at least 20 live animals of each species and 80% should not show any major listed injuries. In the case of killing traps, 80% of 12 test animals should be unconscious within a maximum of 5 min. Put the other way round, 20% could be significantly wounded for a significant length of time, and these traps would still satisfy the criteria. Currently DEFRA issues appropriate licences for the use of certain traps, such as the 'Fenn' trap, or does not permit their use. However, licensing seems to follow little logic; for example, DEFRA tests on the poison bait T3327 MRM showed that the caged foxes convulsed, retched and showed obvious signs of distress before death occurred (Health and Safety Executive 2003). The foxes responded to stimuli during these seizures. T3327 is intended for emergency use in a rabies outbreak and is considered more humane than strychnine, which causes bone-breaking convulsions, haematomas and (in humans) an 'overwhelming fear or hysteria' (Health and Safety Executive 2003) and yet is still currently licensed for use on moles. Some of these poisons can easily affect non-target organisms; for example, T3327 is classed as 'potentially extremely dangerous to fish or other aquatic life' (Health and Safety Executive 2003) and also children, birds and pets.

DEFRA's licensing system is by no means comprehensive or all-embracing. For example, the common break-back mouse trap is not covered by the ISO trapping standards; and DEFRA, in its Assessment of Humaneness of Fully Approved Vertebrate Control Agents (DEFRA 1997), noted "As severe discomfort, which can last for several days, occurs in a large proportion of all the reported studies, anticoagulant rodenticides must be regarded as being markedly inhumane". Welfare standards are at present context-dependent. In pest control, welfare is treated as a secondary priority over efficiency in many cases, and the application of standards and controls is clearly unbalanced.

In Table 2 the fox-shooting regimes that meet government guidelines are shown in bold. They do not all produce results that meet the standards set for other killing methods. Perhaps these guidelines could be refined in the light of our findings, and made mandatory. Also, perhaps education of shooters, including a test linked to the issue of shotgun or firearms certificates, might have a welfare benefit. In the wider context, surely standard welfare benchmarks of acceptability should be established for all methods of killing wildlife, and then applied even-handedly?

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